the silicified form we have had many records of archegonia from BRONGNIART[6] and RENAULT.[7] The latter devoted considerable time and attention to palaeozoic bacteria, and was the first to record tissue formation in a pollen grain. In calcified material archegonia are found preserved in the megaspores of the Lepidodendreae, and recently SCOTT[8] has recorded the early stages in the germination of fern spores. Still more recently I have had occasion to record a very early stage in the development of the embryo sac in the young megasporangium of Miadesmia.[9] But even with instances such as these, we should not have ventured to identify these antherozoids if it had not been for the antecedent discovery in Ginkgo and the cycads of this type of male gamete. As students of phylogeny, we may well congratulate ourselves that such forms as *Ginkgo biloba* and *Microcycas calocoma* persist to the present time to interpret to us the elaborate pollen chambers of the palaeozoic era. In their turn these paleozoic structures are now giving us some evidence of the great antiquity of the cycad type of male gamete.—MARGARET BENSON, *Royal Holloway College, London University.*

THE EMBRYO OF CERATOZAMIA: A PHYSIOLOGICAL STUDY

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY **111**

(WITH SEVEN FIGURES)

Ceratozamia is a genus of cycads of the American tropics. Its habit and habitat and the manner in which the ovules are shed shortly after fertilization are described by CHAMBERLAIN (**1**) in his preliminary note to the study of the reproductive structures.

The embryo has only one cotyledon. This fact was observed by VAN TIEGHEM (**2**) as early as 1873 in a form which he considered a hybrid between *C. longifolia* and *C. mexicana*, but which was probably pure *C. longifolia*. In 1878 WARMING (**3**) recorded the monocotyledonous condition of the embryo of *C. mexicana*, adding that the cotyledon arises at one side of the hypocotyl axis and little by little comes to surround it.

Being engaged in an anatomical study of the seedling, the first observation I made was naturally upon this character. In every case in over one

[6] BRONGNIART, A., Recherches sur les graines fossiles silicifies. Paris. 1881.

[7] RENAULT, B., Flore fossile d'Autun. Paris. 1896.

[8] SCOTT, D. H., The occurrence of germinating spores in *Stauropteris Oldhamia*. New Phytol. **5**:170–172. 1906.

[9] BENSON, MARGARET, *Miadesmia membranacea*, a new paleozoic lycopod with a seed-like structure. Phil. Trans. Roy. Soc. London B **199**:409–425. *pls. 33–37*. 1908.

hundred ovules germinated in 1906, the embryos bore only one cotyledon (*figs. 1, 2, 3*).

When the anatomical study was completed, a preliminary note was received from MATTE (4), who had germinated some seeds provided by CHAMBERLAIN and had begun the study, not knowing that the work was being carried on in this laboratory. MATTE reports that the embryo is monocotyledonous. CHAMBERLAIN (14) in his recent report on Ceratozamia, read before the Chicago meeting of the Botanical Society of America, makes the same statement.

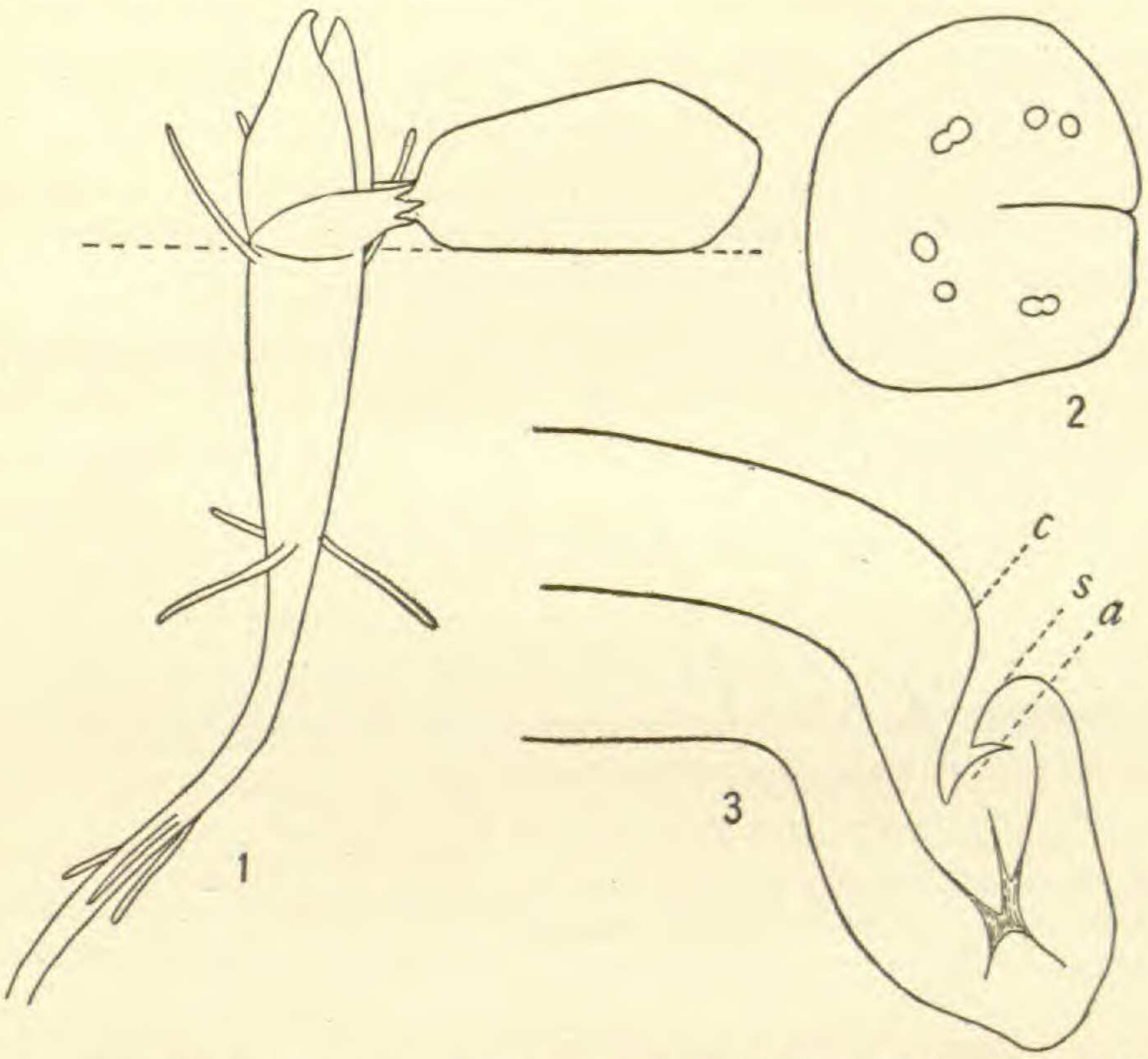


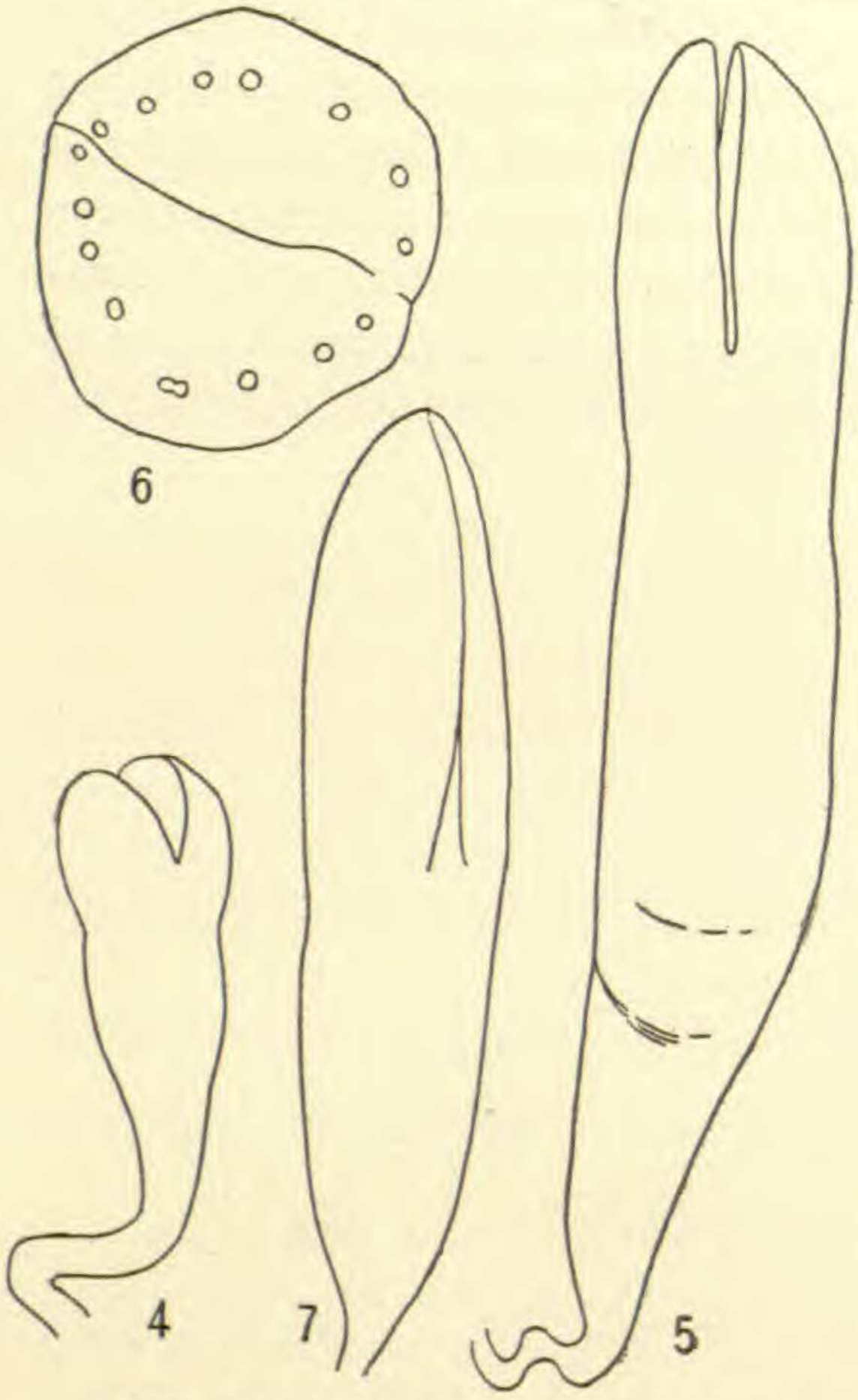
FIG. 1.—Seedling of Ceratozamia showing base of the cotyledonary petiole encircling the stem. Natural size.

FIG. 2.—Cross-section of middle region of cotyledon. ×8.

FIG. 3.—Longitudinal section of seedling in the emergent stage: *c*, cotyledon; *s*, scale; *a*, growing point of stem. ×8.

In other cycad embryos, the cotyledons are often reported as unequal in size. TREUB (5) observed and figured the inequality in *Cycas circinalis*. WORSDELL (6) described a seedling of *Cycas revoluta* in which one cotyledon was considerably shorter than the other. MATTE (7) reports a case in *Dioon edule* in which the vascular strands in the smaller cotyledon are reduced in number, only the rudiments of the missing ones occurring at the base of the cotyledon. He also mentions an inequality in

the size of the cotyledons of *Encephalartos Barteri*. BOWER (8) recorded a difference in the size and anatomy of the two cotyledons of *Cycas Seemanni;* and LAND (Chicago) has noted (unpublished) a difference in the size of the cotyledons of *Zamia integrifolia*.



FIGS. 4 and 5.—Embryos developed on clinostat; removed February 3. ×8.

FIG. 6.—Cross-section of middle region of cotyledons of an embryo removed from clinostat February 26. ×8.

FIG. 7.—Embryo taken from soil in green house January 8. ×8.

Outside the cycads one finds the same tendency in seeds of similar habit. SOLMS-LAUBACH (9) figured it in an embryo of *Bennettites Gibsoniana*, a fossil relative of the cycads; and COULTER and CHAMBERLAIN (10) and LYON (11) have recorded it of Ginkgo.

In the course of my anatomical study, I noticed that the cotyledon was a lateral structure and that there was absolutely no external trace of another (*fig. 3*), but certain irregularities in the vascular system made me suspect that the second cotyledon had been suppressed. These irregularities consisted mainly in the suppression of one pole of the root, and the presence of certain rudimentary strands which joined the stem in normal fashion, but whose upper portions ended blindly in the cortex or fused with other bundles. The suspicion was strengthened by the observation that in every case the cotyledon developed on the under side as the seed lay. This latter circumstance led me to think that gravity was responsible for the monocotyledonous condition.

In the following autumn, therefore, fresh ovules were placed in broad pots, covered closely with sphagnum, and placed upon clinostats revolving at different rates of speed. In December the LIVINGSTON porous cup apparatus (12) was inserted in order to equalize the soil moisture. At the same time fresh seeds were planted in the greenhouse.

The apparently simple plan of planting the seeds end down was not adopted for two reasons. First, this would not give accurate results, because such a seed as that of Ceratozamia could not be placed and kept in an exactly vertical position, and there is no doubt that a variation from the vertical of only a few degrees is sufficient to bring an organ under the direct influence of gravity. Second, at the time of formation of the growing points, the embryo has been pushed half-way through the massive endosperm in a tortuous and winding path by the elongating suspensor, and it is probable that just at the time when it comes to rest, gravity will determine its position whether the seed be vertical or horizontal.

Rotation on the clinostat seems to have retarded development to a marked degree, but has not otherwise interfered with it. Early in February, the embryos developing on the clinostat were found to have two equal cotyledons (*figs. 4, 5, 6*), while those developing under normal conditions have only one (*fig. 7*). Further, the dicotyledonous embryos have a tetrarch stele in the root and the cotyledonary vascular system is of the usual cycad type.

It can scarcely be doubted that gravity is the main factor in bringing about the inequality reported in the cotyledons of other gymnosperms, and it may be that further experiment will throw some light upon the seeming suppression of root poles. It is possible also that it is to this cause we may attribute not only the monocotyledonous condition long known to exist in some dicotyledons, mentioned by COULTER and CHAMBERLAIN (13); but even the condition of certain true monocotyledons whose embryos from their very inception hold a practically unchanged one-sided relation to gravity.

The experimental work is under the direction of Professor CHARLES R. BARNES and Dr. WILLIAM CROCKER.—HELEN A. DORETY, *The University of Chicago.*

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